84- 4683

Copies of this publication may be obtained from:

Print Media Branch
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ISBN 0-7732-0[illegible]-[illegible]

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS

IN EVALUATING

MANURE MANAGEMENT SYSTEMS

BY

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ALBERTA AGRICULTURE

JUNE, 1984

ACKNOWLEDGEMENTS

I want to thank all who assisted me in writing this publication on manure management systems. Special thanks goes to Brian West, Livestock Waste Management Engineer, Alberta Agriculture for his direction, patience and review of various drafts. The staff of Production and Resource Economics Branch also played a critical role in helping me complete the publication.

Comments and suggestions from Don Laverty, Soil and Feed Testing Lab and from Adolf Goettel and Doug Penney, Soils Branch were most valuable.

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SECTION I

INTRODUCTION

Most research papers, brochures and journal articles refer to livestock and poultry manure as a waste product. The idea is a carryover from the days when fuel and fertilizer were inexpensive and manure was considered a nuisance to be disposed of in the cheapest way possible. However, in today's world of relatively high priced inputs, farmers can no longer afford to think of manure simply as a waste product. Instead it should be considered a resource to be used as efficiently as possible.

Manure that is collected, stored and utilized in an effort to minimize nutrient losses can go a long way in replacing commercial fertilizers and reducing the energy used in the manufacture of commercial fertilizers. In addition, technology now allows some farms to process manure and use it as a substitute for conventional sources of fuel or as a livestock feed.

One reason more attention has not been paid to proper handling, storage and utilization of manure is that the value of manure has not been adequately demonstrated. Farmers today still question whether it is economical to use manure instead of commercial fertilizer. Also, there is a lack of information to show whether a farmer can afford to incorporate manure into the soil (instead of just spreading it on the surface) and how custom manure handling costs compare with having one's own equipment. There are conflicting reports on the technical and economic feasibility of composting manure, generating methane gas or electricity from manure and using processed manure as a feed substitute.

Objectives of the Report

The major objective of this publication is to provide a fairly comprehensive report concerning alternatives to some of the current methods of handling manure. Specifically, the objectives are:

1. To provide information showing how with proper handling, manure compares in economic value with commercial fertilizers when used to add nutrients and condition the soil.
2. To show how the costs and benefits of incorporating manure into the soil compare with surface spreading with its inherent loss of nutrients to the atmosphere.
3. To provide data showing how custom manure handling costs compare with the costs incurred by a person who does the work himself.
4. To review the state of the art with regard to a) farmscale composting of manure, b) producing methane from manure and c) refeeding manure. This section of the report provides some cost guidelines and discusses the potential of these manure handling methods as alternatives to land application of raw or decomposed manure for providing higher net returns to the livestock and poultry industries and for reducing environmental pollution problems.

Sources of Data

The data in this publication are the result of the author's having compiled, reviewed and analysed reports on manure handling from across Canada, the United States and Europe. Personal communication with researchers, agricultural engineers, soil specialists, etc. also forms a significant basis for the data.

This report is primarily concerned with the economic feasibility of alternative methods of handling and utilizing manure. Readers who want more detailed information on the agronomic and engineering aspects of manure handling should refer to other sources such as the Canada Animal Waste Management Guide, Publication 1534, available from Agriculture

Canada, Ottawa, Ontario. For information on legislation regarding manure handling and utilization, readers should refer to the publication entitled Confinement Livestock Facilities Waste Management Code of Practice, available from Publications, Alberta Agriculture, 7000-113 Street, Edmonton, Alberta T6H 5T6.

SECTION II

DEVELOPING A SYSTEMS APPROACH TO MANURE MANAGEMENT

Webster's Dictionary defines the word system as "a regularly interacting or interdependent group of items forming a unified whole." Developing a systems approach therefore implies considering all of the items or components that work together or interact to accomplish a particular task or goal.

In a broad context, a farm business is a system where land, labour, capital, and management all combine to provide both a living and a lifestyle for the farm business manager and his family. In a narrower context, a livestock enterprise within the farm business system can be considered as a subsystem or component of the farm business, or a system in itself. Narrowing the context even more, the housing, feed-handling or manure-handling components of the livestock enterprise or system are often referred to as systems, even though they are technically only components of a larger system, because they must work harmoniously with other components or subsystems if the farm is to function efficiently. For purposes of this report, a manure management system will be defined as all of the components, including facilities, machinery, equipment, labour and management, that work together in providing a means of handling manure to the satisfaction of the farmer and the environment.

Selecting a manure handling system for a specific farm or feedlot involves considering many factors. Comparative costs (both capital and operating), labour requirements, land available for manure application, the potential for air or water pollution, operator preference, and the dependability and flexibility of each system all need to be evaluated.

Livestock or poultry producers who are already established, but want to expand the size of their operations or need to change the way in which they handle manure, may not have many alternatives. They may be more or less locked into a situation, unable to change the type of "housing" or the land base available on which to use the manure. The lack of capital may also limit their options.

Persons planning to construct new livestock or poultry facilities have a better opportunity to develop the best manure handling system for their particular situation. It may be helpful to begin by considering how the manure will ultimately be used and then working backwards to develop a system that will tie in well with "housing", feeding, etc. Begin by asking questions such as: How much land is available on which to spread or incorporate manure? What quantity of manure will have to be handled annually? How much time will be available for manure handling and overseeing the system? How much capital is available to invest in a manure handling system and what is the cost of capital? Are odors likely to create a nuisance? The answers to these questions will assist in determining which systems could be considered and which would not be suitable.

In most situations direct land application of manure will prove to be the most efficient means of utilization or disposal. However, if land application of raw manure is likely to create a pollution problem, there are several alternatives. For example, it might be feasible to (a) compost the manure prior to either applying it to the land or marketing it directly to neighboring farmers or indirectly to gardeners and greenhouse operators via garden shops, grocers, etc; (b) process and recycle some or all of the manure as a livestock feed product; or (c) set up a methane generating plant that will produce energy to heat farm buildings or run a generator to produce electricity.

A few farmers and feedlot operators scattered throughout North America are successfully using one or more of these alternatives to direct land application of raw manure. Most are large-scale livestock or poultry producers and most have experienced their share of problems in getting set up to compost, re-feed or produce methane from manure.

Before embarking on one of these methods of utilizing manure, one should spend some time determining just how practical and worthwhile the method will be. For example, a methane generator or recycling equipment will not decrease the volume of manure very much. Most of the product will still have to be land applied. Therefore, a current disposal problem is not likely to be overcome as a result of installing a methane generating facility.

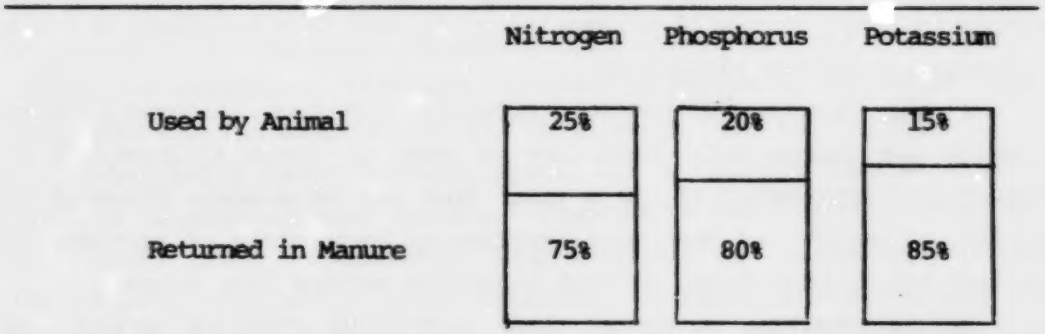
Section VI of this report discusses each of these alternatives in greater detail.

SECTION III

QUANTITY AND POTENTIAL VALUE OF LIVESTOCK AND POULTRY MANURE

The major plant nutrients that are supplied by both commercial fertilizers and manure are nitrogen (N), phosphorus (P), potassium (K) and sulpher (S). These nutrients are usually expressed as percentage of nitrogen (N), phosphate (P_2O_5) potash (K_2O) and sulphur (S). In addition to N, P, K, and S, manure also contains relatively large amounts of calcium and magnesium, as well as trace amounts of manganese, boron, copper and zinc, all of which are needed for plant growth. Only about one-fifth of the three major nutrients that an animal consumes is absorbed into the body. The other four-fifths are excreted in the manure, as shown in Figure 1.

Figure 1: The Approximate Percentage of the Plant Nutrients in a Feed That are Absorbed into the Animal Body and the Approximate Amounts Excreted in the Manure - Liquid and Solid.



Source: Miller, H.F. et al. Farm Manure: Production-Value-Use. Interdepartmental Publication 19. U. of Kentucky, College of Agriculture. 1976

Capturing as many of these nutrients as possible and putting them to another use on the farm would seem to make sense. Where manure can be used in place of commercial fertilizers, its value often extends beyond simply supplying Nitrogen, Phosphorus and Potassium. Micronutrients in the manure may be of value in some soils and the organic matter which the manure adds to the soil will provide a source of energy for micro-organisms and is essential for good soil structure or tilth.

The quantity of manure on a particular farm or feedlot depends on many factors such as the number, type and size of livestock or poultry, their ration and the length of time they are kept. The type of ration affects both the nutrient content and the quantity of manure. High roughage rations result in larger quantities of manure being excreted and therefore higher handling costs. This larger quantity of manure will, however, have a higher dollar value, partially offsetting the higher handling costs.

The type and amount of nutrients in manure, and the eventual availability of these nutrients depend on the species of poultry or livestock, the amount and type of feed, whether bedding or water is added, the method of manure collection and storage, and the length of storage.

Table I provides some data on approximate quantities of manure (feces and urine) produced by various farm animals and poultry according to their respective weights. This table also shows the approximate amounts of nitrogen, phosphorus and potassium present in the manure excreted and the potential value prior to any loss of nutrients in storage and handling. In actual fact, the quantity of manure produced, the composition and therefore the potential value of manure, based on its nutrient content, can vary considerably. Individuals who plan to utilize manure for crop production would be well advised to analyse manure samples for nutrient content, as well as soil samples for nutrient requirements.

According to the data in Table I, the manure from a 1,000 head beef feedlot would have a potential nutrient value of $56,760 per year, assuming the cattle weigh an average of 750 pounds during the time they are in the feedlot. Similarly, a 10,000 bird layer operation would generate about $6,400 worth of manure nutrients annually.

TABLE I: MANURE PRODUCTION RATES, APPROXIMATE NUTRIENT CONTENT AND VALUE OF NUTRIENTS AT TIME OF EXCRETION

Animal/Bird	Size lb.	Total Manure Production lb/day	cu.ft/day	gal/day	Water %	Nutrient Content N lb./yr	P^1 lb./yr	K^2 lb./yr	Nutrient Value[3] $/year
Dairy Cattle	1400	115	31.85	13.9	87.3	210	51	138	194.61
Beef Cattle	500	30	.50	3.8	88.4	62	20	44	37.84
	750	45	.75	5.6	88.4	93	30	66	56.76
	1000	60	1.00	7.5	88.4	124	40	88	75.68
Cow	-	63	1.05	7.9	88.4	131	44	95	81.43
Hogs	35	2.3	.04	.27	90.8	5.7	1.9	3.8	3.50
	65	4.2	.07	.48	90.8	11.0	3.6	7.1	6.63
	150	9.8	.16	1.13	90.8	25.0	8.2	16.0	15.05
Sow	275	8.9	.15	1.1	90.8	23.0	7.7	15.0	13.99
Sow & Litter	375	33.0	.54	4.0	90.8	84.0	28.0	55.0	51.07
Sheep	100	4.0	.06	.46	75.0	16.0	2.4	12.0	8.08
Poultry									
Layers	4	.21	.004	.03	74.8	1.05	.41	.45	.64
Broilers	2	.14	.002	.02	74.8	.85	.19	.26	.40

1 $P \times 2.3 = P_2O_5 \times 0.43 = P$

2 $K \times 1.2 = K_2O \times 0.83 = K$

3 Values are calculated assuming a retail price for N of 28¢, P of 65¢, (P_2O_5 @28¢) and K of 17¢ (K_2O @14¢) per pound of commercial fertilizer. Changes in the costs of commercial fertilizers will change the value of nutrients shown in this table.

Determining The Actual Value Of Manure

The potential nutrient value of manure only serves to show what the product could be worth if all of the nutrients it contained upon excretion could be fully utilized. However, all handling and storage systems have some nutrient losses associated with them and therefore the figures most often used to show the value of manure are based on the nutrients contained in the manure as it is removed from storage.

Even these figures can be misleading, especially where manure is to be used as a substitute for commercial fertilizers in promoting plant growth. Not all soils are deficient in each of the basic elements, nitrogen, phosphorus, potassium, and sulphur. If, for example, nitrogen is the only element deficient in a particular soil, then the manure would be over-valued if one were to value the phosphorous, potassium and sulphur in the manure.

Conversely, manure may be under-valued if no value is placed on the micro-nutrients when one or more is needed in the soil on which the manure is applied, or if the soil-building and water retention properties of adding manure to the soil are not considered. There seems to be some controversy as to whether adding manure to a soil can actully increase its organic matter level or simply maintain it. According to reports from the University of Alberta[1,2] organic matter is more likely to be maintained through regular additions of manure to a soil. However a study in Ontario[3] showed that annual additions of green rye, straw, alfalfa, leaves, peat, muck and manure to a sandy soil over 20 years increased the organic matter content somewhat. Researchers in Idaho contend that the organic matter of a sandy soil can be improved by one per cent with the addition of 40 tons of manure. See Table II. Assuming

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1 McGill, W.B. Kinetic Effects on Quality of Soil Organic Matter, Proceedings of the 20th Annual Alberta Soil Science Workshop. Edmonton, Alberta. February 22 & 23, 1983.

2 Robertson, J.A. Effect of Management on Soil Organic Matter. Proceedings of the 20th Annual Alberta Soil Science Workshop. Edmonton, Alberta. February 22 & 23, 1983.

3 Sowden, F.J. and Atkinson, H.J. Effect of Long-Term Annual Additions of Various Organic Amendments on the Organic Matter of a Clay and a Sand. Can. J. Soil Sci. 48:323-330. 1968.

this is so, and that about two per cent of the top six inches of soil (two million pounds per acre) is organic matter, cropland valued at $500 per acre would have an organic matter value per ton of manure estimated at 12.5 cents per ton. $\frac{(\$500)(.01)}{40}$

This information suggests that the manure from a 1,000 head beef feedlot, applied at a rate of 20 tons per acre to a sandy soil would improve the organic matter of the soil to a value of $2.50 per acre. Additional economic benefits may accrue as a result of improved water-holding capacity and soil tilth, benefits that are not available when only commercial fertilizers are used.

TABLE II: THE EFFECT OF MANURE APPLICATION ON ORGANIC MATTER CONTENT IN SANDY SOILS

MANURE APPLIED (50% MOISTURE) (TONS/ACRE)	ORGANIC MATTER CONTENT(%)	MARGINAL INCREASE (%)
0	2	
40	3	1
80	4	1
120	5	1
160	6	1
200	7	1

Source: Gilmour, C.M. et al. User's Manual for the Selection and Management of Feedlot Sites and Land Disposal in the Boise Valley. Army Corps of Engineers Advanced Report, Boise, Idaho. 1975

SECTION IV

ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS IN EVALUATING ALTERNATIVE MANURE MANAGEMENT SYSTEMS

A manure handling system that is suitable for a specific farm or feedlot will result when a farmer considers both economic and environmental factors. Among these factors are the current and anticipated size of the livestock operation, proximity to watercourses, proximity to neighbors, availability of land, the potential for recycling manure, labour available to handle the manure, availability and cost of capital, and the investment and operating costs of alternative systems.

Because there are so many factors to consider in deciding which manure handling system(s) are suitable, recommending any "best" system is impractical. Each producer must assess the alternatives and select a system suited to his situation.

Economic Concepts and Considerations

The economic benefits of a well-planned manure handling system generally stem from the fact that nutrients in the manure may be used to replace commercial fertilizers for plant growth. In some cases, the manure may also have economic value as a protein source to replace purchased protein for livestock feeding, or as a material to use in the production of chemical or electrical energy through methane generation.

In determining the costs of alternative manure handling systems, both fixed and variable costs must be considered. Fixed costs such as depreciation, long term interest, insurance and taxes are incurred annually, regardless of the level of production. Costs such as labour, repairs, fuel and electricity vary with the production level.

Determining which are fixed costs and which are variable depends on the length of the planning period. As the length of the planning period increases, more of the fixed costs become variable. In the long run all costs are variable, since the owner may make changes, abandoning

one facility or piece of equipment in favour of another. In the short run, the owner will feel locked in to a particular method as a result of the way in which he can use that facility or piece of equipment.

With nearly every manure handling option, there is a tradeoff between capital and labour requirements. As a result of the scarcity of skilled farm workers and ever-increasing wage levels, the trend is definitely toward more capital intensive and less labour intensive manure management systems. Unfortunately, the price of greater automation is often that the owner of the system ends up with so much capital invested that he can't afford to leave the system idle, thereby reducing his ability to react to changing economic conditions.

Partial Budgets For Determining Costs of Alternative Systems

A partial budget can be useful for forecasting the economic effects of a new or remodelled manure handling system on the entire farm business. Whereas total farm budgets weigh the costs and benefits of all activities in the business, a partial budget considers only those factors that change as a result of implementing a new method or system. As well, several systems or methods may share common components. In such a situation, the costs of these components would not be included in the partial budget.

To better understand the usefulness of a partial budget, consider this example.

> A dairy farmer with a 50-cow milking herd has a stanchion barn with a gutter cleaner. Manure is field spread every day, when weather permits, using a box spreader. The farmer wants to build a manure storage facility so that he can a) do away with the drudgery of daily manure hauling and b) avoid spreading manure on frozen ground several months of the year. He plans to provide for six months of storage by constructing a curbed cement slab with a runoff retention area. A stacker elevator will move manure from the gutter cleaner to the stack area. A front-end loader will load manure into the spreader and manure will be plowed down shortly after spreading to minimize nutrient losses and reduce odor.

Cost data for each method are summarized in a partial budget format in Table IV. (Since costs can vary considerably, these figures should be thought of as an example only, and not used for actual budgeting.)

Table III shows the nutrient and dollar values that each method would likely provide in offsetting the costs associated with it. These figures are incorporated into Table IV to arrive at net annual costs or returns.

TABLE III: PRODUCTION, LOSSES AND VALUE OF NUTRIENTS IN MANURE FROM A 50-COW DAIRY HERD[1]

	CURRENT METHOD			OPTIONAL METHOD		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
			POUNDS			
Nutrients Produced[2]	8950	3650	7300	8950	3650	7300
Nutrient Losses						
Storage[3]	4475	365	1460	3133	365	1460
Volatilization[4]	430			0		
Denitrification[5]	895			1163		
Total Losses	5800	365	1460	4295	365	1460
Nutrients Available For Crop Use	3150	3285	6205	4655	3285	6205
			DOLLARS			
Nutrient Value	$882	$920	$869	$1303	$920	$869
Total		$2671			$3092	

1 Average cow weight of 1200 pounds.

2 From Table I

3 Since the current method involves spreading manure on cropland without incorporating the manure, N loss is assumed to be 50 per cent. Storage loss of N for the optional method is assumed to be 35 per cent. P_2O_5 and K_2O losses are 10 and 20 per cent, respectively.

4 Volatilization loss is the amount of N lost during land application in the form of free ammonia. Assumes a cool moist soil.

5 Assumes a moderately well-drained soil.

6 Nutrients valued at $.28 for nitrogen, $.28 for phosphate and $.14 for potash.

TABLE IV: PARTIAL BUDGET EXAMPLE

ECONOMIC ANALYSIS OF ALTERNATIVE MANURE HANDLING SYSTEMS FOR A 50-COW HERD

	CURRENT METHOD	OPTIONAL METHOD
A. Additional Capital Outlays		
1. Stacker elevator (30 ft.)		$3000
2. Curbed cement storage slab w/runoff retention area		4625
3. Front end loader		3000
Subtotal		10625
Less salvage value		3541
Fixed investment to be amortized over 7 yrs. at 14%		7084
B. Annual Ownership Costs (Fixed investment X amortization factor (0.2332)		$1652
C. Annual Operating Costs		
1. Labour @ $6.50/hr		
a) transfer to storage		326
b) from storage to fields	1367	859
c) plowdown		146
2. Electricity @ $.04/kwh		
a) transfer to storage		24
3. Fuel (@ $30/L) Lube and Repairs		
a) transfer to storage		130
b) from storage to fields	857	607
c) plowdown		225
Total Annual Operating Costs	$2224	$2317
D. Increased Annual Costs [1]	$2224	$3969
E. Returns from manure as plant nutrients [2] (from Table III)	$2671	$3092
F. Net Annual (Costs) or Returns	$447	($877)

Optional Method - 180 day slab storage, stacker elevator, twice a year field spreading.

1 Does not include cost of gutter cleaning or manure spreader which are common to each alternative.

2 Assuming that crop requires all nutrients.

Source: Based on a similar example by L. A. Christensen et al. Managing Animal Wastes - Guidelines for Decisionmaking. Economic Research Service 671.U.S.D.A.. 1981.

In this example, the dairy farmer can see that the additional costs associated with an investment in manure storage would place him in a worse financial situation. He would have to justify the investment based on non-economic factors, such as not having to haul manure daily. Another type of storage system which would save more of the nutrients in the manure may be economically feasible or the same storage method used for a larger dairy herd may also save money.

Environmental Considerations

Intensified livestock production methods have increased the potential for air, soil and water pollution. The encroachment of urban residences into areas that were once considered agricultural has increased the chances of livestock producers coming into conflict with their neighbors over "nuisances" such as odors or flies.

A well designed manure handling system for a farm or feedlot will not only attempt to reduce or eliminate the impact of manure on the surrounding environment, it will also reduce any harsh environmental effects on the animals themselves. Windbreaks, mounds, solid surfaces and good drainage to runoff collection facilities outside the area enclosing the livestock will reduce the stresses placed on livestock by wind, mud, flies, dust, etc. Additional growth and weight gains may well compensate for the added costs of providing a better environment.

Unlike the United States, Canada has minimal legislation protecting the environment from agricultural pollutants. Nevertheless, producers are becoming increasingly aware of the need to protect the environment and the majority of livestock and poultry manure handling systems are being designed and built with some form of pollution control in mind.

Installing manure handling systems to minimize odor and runoff problems usually involves construction of additional facilities to divert clean water or to store the manure for longer periods. These facilities add to the capital costs. These added costs can generally be offset, or at least partially offset, by the fact that more nutrients can be recovered, having a higher economic value as replacement for commercial fertilizers, purchased protein, or energy in the form of natural gas, propane or electricity.

SECTION V

AN ECONOMIC EVALUATION OF CONVENTIONAL METHODS OF UTILIZING RAW AND DECOMPOSED MANURE

It is generally accepted that applying livestock or poultry manure to the land is the most practical and cost effective method of utilizing the product. Land application of manure has proven to provide some insurance against high prices and possible shortages in supply of commercial fertilizers.

This section looks at some of the factors that affect the value of manure when it is applied to cropland. It also discusses various methods of utilizing manure, as well as relative costs and returns when manure is used to provide nutrients for crop production.

Factors That Affect The Value of Manure

The most significant factor affecting the nutrient level of manure at the time of land application is the method used to collect and store the manure.

Table V shows that nitrogen losses vary considerably among methods of handling and storing manure. Considerable nitrogen is lost when manure undergoes long periods of exposure to air or runoff water, as is usually the case in an open lot. In contrast, an enclosed facility that uses a manure pack, deep pit or a liquid storage tank or pit has very little nitrogen lost.

Partial treatment systems, such as oxidation ditches or lagoons, contribute to very high nitrogen losses, a situation which may be desirable if manure must be applied to a small land area. In most cases, however, these methods of storing manure ultimately result in lost revenue to the livestock or poultry producer.

With the exception of open lot or lagoon storage of manure, phosphorus and potassium losses are only 5 to 20 per cent. In an open lot, about 50 per cent of the phosphorus and 40 per cent of the potassium

may be lost as a result of runoff and leaching. In a lagoon, up to 80 per cent of the phosphorus may be lost.

TABLE V: NITROGEN LOSSES FROM MANURE AS AFFECTED BY METHOD OF HANDLING AND STORAGE

Handling/Storage Method	% Nitrogen Loss[1]
Solid Systems	
Daily scrape and haul	15 - 35
Manure pack	20 - 40
Open lot	40 - 60
Deep pit (poultry)	20
Liquid Systems	
Anaerobic pit or above ground tank	to 30
Earthen storage pit	20 - 40
Oxidation ditch	70 - 90
Lagoon - Aerobic	70 - 80
- Anaerobic	10 - 30

[1] Based on composition of manure applied to land versus composition of freshly excreted manure, adjusted for dilution effects of the various systems.

SOURCES: 1. Sutton, A.L. et al. Utilization of Animal Waste As Fertilizer. ID - 101 (1975) Cooperative Extension Service, Purdue University, West Lafayette, Indiana and
2. Sutton, A.L. 1981. Maximizing the Value of Swine Manure. Pig America, May, p 14-16.

Maximizing The Benefits Of Manure As A Fertilizer And Soil Conditioner

For the last quarter of 1983 total farm input costs were up 313 per cent over the base period 1971 and commercial fertilizer costs were up 320 per cent over that same base period[1]. Increases in petroleum prices (although at a slower rate than during the 1970s) and higher transportation costs during the 1980s will likely continue to cause fertilizer

[1] Farm Input Price Index, Statistics Canada, Ottawa.

prices to rise. This puts pressure on farmers to do what they can to reduce fertilizer input costs, while at the same time maintaining high yields.

Action may take the form of heavier reliance on crop rotations using legumes to supply some of the nitrogen requirements of cereals grown in the rotation. However, grain farmers with access to livestock or poultry manure have another option - judiciously applying this manure to cropland to supply all or most of the nutrient requirements of subsequent crops and supplementing with commercial fertilizers when necessary.

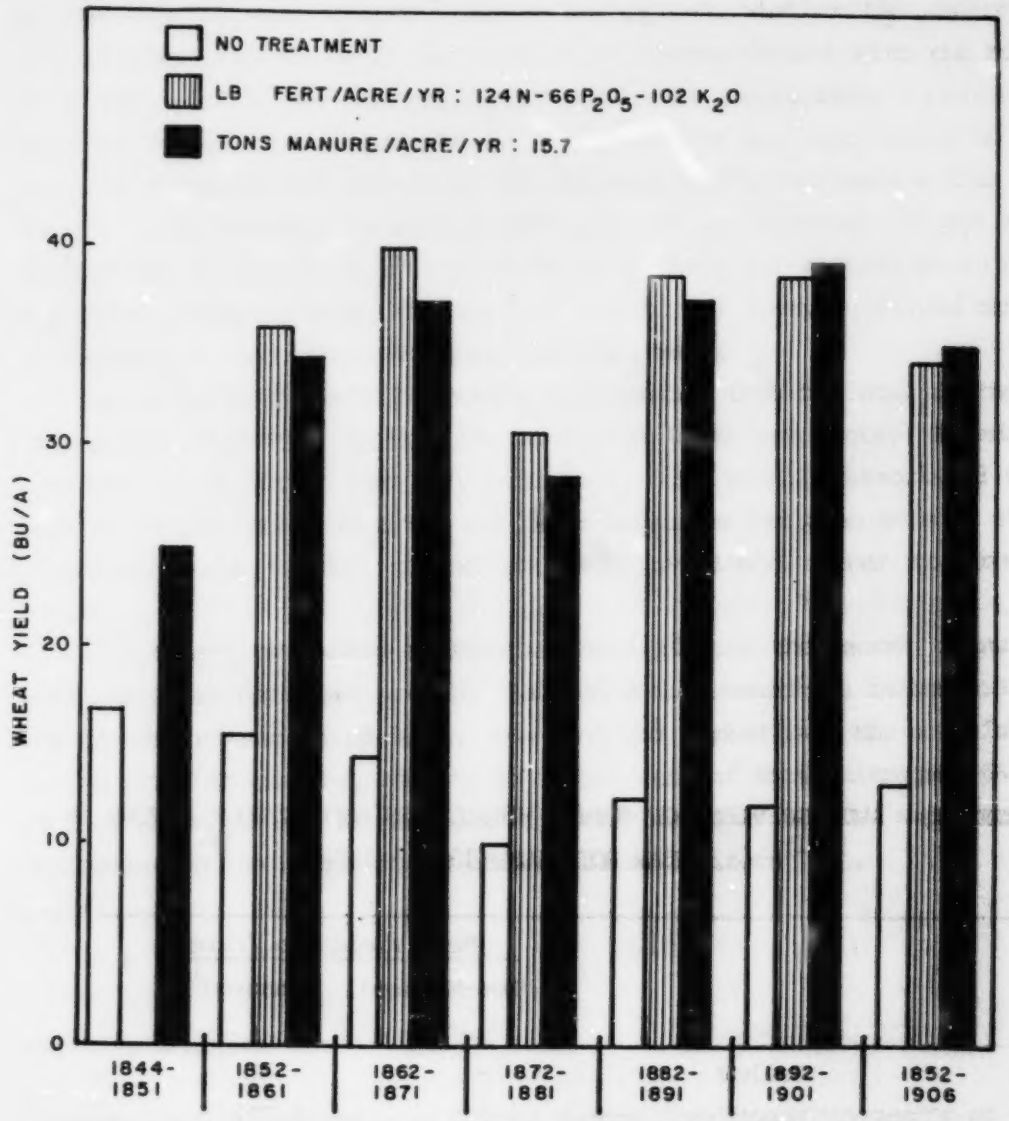
A classic example of the beneficial effects of manure in maintaining the productivity of a soil is the Rothamsted Experiment Station plots in England, as shown in Figure 2, where crop yields on manured and fertilized plots were compared over 53-years. According to the graph, crop yields on manured plots once lagged behind yields on fields where commercial fertilizer was applied, but in the long run the yields on manured plots were slightly better.

Closer to home, the Agriculture Canada Research Station at Indian Head Saskatchewan has compiled data since the mid 1940s showing the long term effects of manure on wheat yields in a wheat-wheat-fallow rotation (Figure 3). During the early years of the experiment, only modest increases in yield occurred. However, after about 10 years, dramatic yield increases were seen.

Similarly, data from the Agriculture Canada Research Station, Lethbridge, show that when 5 tons/acre of manure were added during the fallow year of a three year rotation, wheat yields increased an average of 150 lb./acre during the two cropping years (Table VI).

It is quite possible, or even likely, that the long-term yield increases in experiments such as these occur because the beneficial effects of using manure as a fertilizer extend beyond the ability of the manure to supply essential minerals. With annual applications of manure to the land, the water-holding capacity and infiltration rate can be expected to increase. The structure of the soil also improves, thus allowing for better aeration and the ability of roots to more readily penetrate the soil. Studies also show that wind erosion can be reduced dramatically by

FIGURE 2: Effect of Cattle Manure on Wheat Yields Over a 53 Year Period - Rothamsted Experiment Station, England.



Source: Beef Cattle Waste Management Alternatives. North Carolina Agricultural Extension Service. Circular 571. March 1974.

FIGURE 3: Effect of Manure on Fallow Seeded Wheat in a Wheat-Wheat-Fallow Rotation, Ag. Canada Research Station Indian Head, Saskatchewan.

TABLE VI: AVERAGE YIELD OF SPRING WHEAT WITH AND WITHOUT MANURE IN A 3 YEAR ROTATION (1951 - 1975)

	Mean Yield (lb./acre)	
	Non-Manured	Manured[1]
Fallow	-	-
Wheat	1,716	1,782
Wheat	972	1,056
Total	2,688	2,838

[1] 5 tons/acre in fallow year.

increasing the fibre content of the soil through incorporation of manure, something more farmers should think about.

The availability of nutrients from manure to a growing crop depends on the time of year when the manure is applied, whether the manure is incorporated into the soil where it is in closer contact with the roots of growing plants, and how quickly the manure is incorporated to minimize nutrient losses to the atmosphere. The method of applying manure to the land has a significant effect on what happens to the nutrients within the manure. The methods generally used are (a) broadcasting on the soil surface (b) broadcasting with plowdown or disking (c) knifing or injecting manure directly under the soil surface or (d) spraying liquid manure on the soil surface through irrigation equipment.

As shown in Table VII, manure incorporated into the soil during or immediately following application loses the least nutrients. Immediate plowdown or injection not only minimizes odors usually associated with putting manure on the land but soil microorganisms are also able to start decomposing the manure, making nutrients available sooner to growing plants.

The timing of manure application also affects the amount of nutrients available for plant growth. According to researchers in the U.S., a ton of manure that is spread on the land and worked into the soil in the spring prior to seeding, results in 75 per cent of total nitrogen, 66 per cent of phosphate and 75 per cent of potash being available, expressed as equivalent to the nutrients in commercial fertilizers[1,2].

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[1] Morris, W.H.M. Economics of Liquid Manure Disposal. Management of Farm Animal Wastes, ASAE Publication No. SP-0366, p. 126-131 May 1978.

[2] Nordstedt, R.A., H.J. Barre and E.P. Taiganides. A Computer Model for Storage and Land Disposal of Animal Wastes. Livestock Waste Management and Pollution Abatement. American Society of Agricultural Engineers. St. Joseph, Michigan, April 1971.

TABLE VII: NITROGEN LOSSES TO THE ATMOSPHERE AS AFFECTED BY METHOD OF LAND APPLICATION

Method of Application	Type of Manure	Nitrogen Loss
		%
Surface Broadcast	Solid	15 - 30
	Liquid	10 - 25
Broadcast With Cultivation (immediately after application)	Solid	1 - 5
	Liquid	1 - 5
Knifing (injection)	Liquid	0 - 2
Irrigation	Liquid	30 - 40

Source: Sutton, A.L., et al. Utilization of Animal Waste As Fertilizer. ID-101 (1975), Cooperative Extension Service, Purdue University, West Lafayette, Indiana.

Winter application of manure on frozen ground often results in a large percentage of the nitrogen and some phosphorus being carried away in spring runoff. Of course, the amount of nutrients lost depends on the moisture level of the soil at freeze-up, topography of the land, whether the manure is spread on barren or snow-covered ground and whether the ground is fallow or has a "cover-crop". Having sufficient storage to avoid spreading manure on frozen ground becomes very important if an ojective of the farmer or rancher is to make maximum use of the nutrients in manure.

The Economics of Plowdown or Injection of Manure

Placing manure under the soil surface fulfills two purposes: (a) reducing nitrogen losses from volatilization and runoff of nitrogen and other nutrients, and (b) reducing odor problems. Although these purposes appear worthwhile, the economics of spreading and incorporating manure into the soil or injecting it directly beneath the soil surface, rather than just spreading it, are still under question.

Farmers look at the extra labour and energy required to incorporate manure, as well as the possibility of needing new equipment, and wonder whether they can save enough of the nutrients to justify additional costs. The following pages provide examples of how one might determine whether the added costs associated with plowdown or injection of manure can be offset by the value of nitrogen saved when manure is placed below ground rather than spread on the surface.

The threat of odor problems shutting down a livestock or poultry operation can be a big determinant in whether manure is spread on the surface or incorporated. Runoff into a watercourse can also create the need for manure to be worked into the soil.

Livestock or poultry producers located close to urban residences, light industry or watercourses may have no alternative but to incorporate manure, or face a shutdown of their business. In this situation some value needs to be placed on odor control in determining the economic benefits of incorporating manure. In other situations, where livestock or poultry operations are separated from the nearest neighbors, odor control will be unimportant and little or no value should be placed on it.

If manure is spread on crop land and then plowed down, a value may be given to the tillage if this operation is part of the normal soil management practice. Whether a value should be given to tillage when manure is injected depends on the situation. Spacing of the injectors, depth of injection, etc. will determine if the soil surface is disturbed enough to act as a tillage operation.

Injection costs are easier to justify when highly concentrated forms of liquid manure are to be handled, compared with lagoon effluent where much of the nitrogen value has been lost to volatilization. An example of the economic benefits that can accrue from injecting manure is given in Table VIII. These benefits would be offset by additional costs for injection, shown in Table IX.

TABLE VIII: BENEFITS THAT CAN ACCRUE FROM INCORPORATING MANURE[1]

	Benefit/1000 gal
N savings from Plowdown (20%)[2] or Injection (23%)	$2.80 - $3.22
Tillage credit	$nil - $ .67[3]
Odor Control[4]	$nil - $5.00
Total Estimated Benefits/1,000 gallons	$2.80 - $8.89

1 Assuming liquid manure from a finishing hog operation is applied to stubble at a rate of 6000 gal/acre, providing 300 pounds of N/acre, with commercial nitrogen priced at 28¢/pound.

2 See Table VII, which shows N losses as high as 25% from surface spreading, 5% from surface spreading followed by cultivation (incorporation) and 2% from injection (knifing).

3 Assumes that tillage would be needed in any case. Based on a cost of $4.00/acre for chiseling. Injector spacing is assumed to be twice the spacing of a chisel plow and therefore only 1/2 the credit of chiselling is assigned to injection.

4 Depends on field location in relation to neighboring residences, etc. This factor may or may not be important.

TABLE IX: ADDITIONAL COSTS FOR MANURE INJECTION (300 LB N/ACRE)

	Cost/1000 gal.
Additional Tractor Use[1]	$ .57
Additional Fuel for Injecting[2]	$ .21
Additional Labour[3]	$ .23
	$1.00

Original Cost of Injector	Annual[4] Cost	Annual Breakeven Volume (gallons)[5] N Savings Only	N Savings, & Tillage Credit[6]	N Savings, Tillage Credit & Odor Control
$3200	$800	360,360	313,725	105,960
$4200	$1050	472,973	411,765	139,073
$5200	$1300	585,586	509,804	172,185

1 Two minutes/1000 gal. @ $17/hr. for depreciation, interest and repairs on a 180 hp tractor. (Farm Machinery Costs publication. Agdex 825-12, Alberta Agriculture, March 1982.)

2 One-half the fuel required for chiselling = 1.0 gal/ac @$1.25/gal. (Assuming that the injectors are spaced at twice the spacing of a chisel plow.)

3 Two minutes/1000 gal. @ $7.00/hr.

4 Assumes 14% interest, 3% repairs and a 7 year life with 10% salvage value giving 8% annual depreciation for a total annual cost of 25%.

5 Estimated benefit minus additional cost/1000 gallons equals "X". Annual cost divided by ("X" times .001) equals number of gallons.

6 Tillage credit calculated at $.33/1000 gallons since injectors are spaced at twice the spacing of a chisel plow.

If a $3200 injector unit is mounted on a 2250 gallon liquid manure tank, approximately 360,000 gallons of manure would have to be hauled annually just to pay for the extra costs of injection if a nitrogen

saving was the only benefit from injection. Only 106,000 gallons would have to be hauled if nitrogen saving, tillage and odor control could be credited.

To compare the costs and benefits of plowdown with direct injection, assume that a farmer has a new 25-foot heavy duty cultivator (or chisel plow) that can be used to incorporate the manure immediately after it is spread. A 180 hp two wheel drive tractor will be used to pull the cultivator.

Table X shows the additional costs and benefits per thousand gallons of manure plowed down.

TABLE X: ADDITIONAL COSTS/BENEFITS FOR MANURE PLOWDOWN (300 LB N/ACRE)

	Cost/1000 gal	Benefits/1000 gal	
Additional Tractor Use[1]	$ .21	N savings	N savings,
Additional Fuel for Plowdown[2]	$ .42	& tillage	tillage
Additional Labour[3]	$ .09	credit	credit &
Additional Cultivator Use[4]	$ .18		odor control
	$ .90	$3.47	$8.47

1 Based on a work rate of 13 acres/hour or 4.6 minutes/acre and $17/hr. for depreciation, interest and repairs on a 180 hp tractor.

2 Two gallons/acres @$1.25 gallon ÷ 6 (6000 gal/acre)

3 4.6 min./acre ÷ 6 (6000 gal/acre) = .77 min/1000 gal x $7.00/hr

4 From the publication Farm Machinery Costs, Agdex 825-12, Alberta Agriculture, March 1982.

Table IX determines the number of gallons of liquid manure that would have to be hauled annually to offset the extra costs of injection.

Assuming that plowdown would provide extra benefits of nitrogen savings and tillage control, the following costs and benefits would accrue if the same number of gallons shown in Table IX were plowed down instead of injected.

	Costs	Benefits
N Savings & Tillage Credit		
105,960 gallons	$ 95	$368
139,073 gallons	125	483
172,185 gallons	155	597
N Savings, Tillage Credit & Odor Control		
313,725 gallons	$282	$2,700
411,765 gallons	371	3,488
509,804 gallons	459	4,318

Innovations to Increase the Value of Liquid Manure

Two U.S. innovations in ways of making more efficient use of liquid manure as a substitute for commercial fertilizers are worth noting. Both warrant research to determine their value under conditions in western Canada.

A. Anhydrous Fortified Liquid Manure:

An anhydrous tank is hooked to a tractor-pulled or truck-mounted slurry tanker equipped with injector chisels for knifing in the anhydrous fortified liquid manure. This method is particularly adaptable where there is sufficient land for manure application. The rate of application can be geared to meeting the phosphorus requirements of the soil while applying additional nitrogen in the form of anhydrous ammonia. This procedure allows the farmer to apply liquid manure to a larger area and reduces the chance of applying too much phosphorus.

B. Using a Nitrification Inhibitor With Liquid Manure:

Although nitrification inhibitors such as N-Serve and Dwell were developed primarily for use with liquid commercial fertilizers, they can be used in a similar manner with liquid manure. Research from Purdue University has shown that, at least under their environmental and soil conditions, N-Serve, marketed by Dow Chemical Company, can

be used to minimize nitrogen losses. In a study with manure injected into the soil in the fall, 3/4 lb. of N-Serve per acre added to 14 tons liquid manure increased corn yields from 75 to 142 bushels, compared with manure without the inhibitor. The additional cost of the inhibitor was about $10 per acre.

A Cost Comparison Of Owning Manure Handling Equipment Or Hiring A Custom Manure Handling Service

An alternative to investing in manure handling equipment that sits idle most of the year is to hire a custom manure handling service. The question is, how do the two options compare in cost? Consider an example where liquid manure is pumped from slotted floor hog feeding barns. Manure is applied to an 80-acre field near the farmstead. A one-mile round trip is required.

EXAMPLE I: LIQUID MANURE HANDLING SYSTEMS

A grain farmer produces 1,000 finishing hogs and 500 feeder hogs annually. At an average weight of 150 pounds for the finishers and 65 pounds for the feeders, the hog operation will produce the following quantity of manure and manure nutrients annually:

	Gallons	N	P	K
		pounds		
500 Finishers[2]	206,225[1]	12,450	4,050	8,050
250 Feeders[2]	43,800	2,750	875	1,750
Total	250,025	15,200	4,925	9,800

1. From Table I.

2. For ease of figuring, the farmer is assumed to have 500 finishers and 250 feeders in the barns for 12 months. In reality, he would purchase weaner pigs in various lot sizes and finish them in approximately 6 months.

Option A: Owning the Manure Handling Equipment

If the farmer chooses to haul manure himself, he will use a 2250 gallon vacuum-type manure tanker priced at $11,000. A 180 hp tractor, already on the farm, will be used to pull the tanker. A separate plowdown operation will be done immediately after the manure is spread (weather permitting) to conserve as many nutrients in the manure as possible. A 125 hp tractor and a 25-foot wide chisel cultivator will be used for plowdown.

One hundred and eleven loads will be hauled to the field at an average rate of 22.5 minutes per load, resulting in a total time requirement of 42 hours or 5¼ days, if manure is hauled for eight hours per day. Equipment and labour costs are shown in Table XI.

TABLE XI ANNUAL EQUIPMENT AND LABOUR COSTS FOR HAULING AND PLOWDOWN OF 250,000 GALLONS OF MANURE USING OWN EQUIPMENT

Equipment Costs	Variable $	Fixed $	Total $
2250 Gallon Tanker	126	420	546
180 hp Tractor	840	504	1344
125 hp Tractor	90	56	146
25 Foot Chisel Cultivator	34	50	84
TOTAL EQUIPMENT COSTS	$1090	$1030	$2120
Labour Costs: 42 hours spreading plus 6 hours plowdown = 48 hours @ $7.00/hour			336
		TOTAL COST	$2456

Option B: Hiring A Custom Manure Handling Service

A manure handling service with a 2200 gallon truck-mounted tanker can be hired to haul the 250,000 gallons of liquid hog manure. The truck is equipped with floatation tires and a mounted injector unit. The job will take the custom operator 24 hours to complete. He will make 114 trips to the field. The cost to the farmer will be one cent per gallon or $2500 total. The actual costs vary according to distance travelled and quantity of manure to be handled.

Although there is hardly any difference in cost between the two options, one also needs to look at whether there is any difference in benefits.

Assuming that nitrogen is valued at $.28 per pound, phosphorus at $0.65 per pound and potassium at $0.17 per pound, the total value of manure nutrients excreted by the hogs would be $9123. The value of manure nutrients for actual plant growth will be reduced according to which nutrients are needed for plant growth and the amounts lost in storage and handling.

Since most soil in Alberta contains sufficient potassium for optimum plant growth, no value is placed on the potassium in this example.

Assume that the hog manure loses 25 per cent of its nitrogen value in storage (see Table V) and an additional five per cent when spread and incorporated immediately or two per cent when injected. Phosphorus loss is assumed to be only 10 per cent.

The result is that the value of manure nutrients useful for plant growth will be $5860 if manure is incorporated or $5988 if it is injected.

Table XII summarizes the differences in benefits and costs for the hog producer who is trying to decide whether he should have his own manure handling equipment or hire a custom manure handling service. In this example, the farmer would be slightly better off hiring the job done.

TABLE XII SUMMARY OF BENEFITS/COSTS FOR OWNING MANURE HANDLING EQUIPMENT OR HIRING CUSTOM MANURE HANDLING SERVICES

	Own Equipment (plowdown)	Custom (injection)
Benefits	$5860	$5988
Costs	2456	2500
Benefits less Costs	$3404	$3488

SECTION VI

ALTERNATIVES TO CONVENTIONAL METHODS OF HANDLING AND UTILIZING MANURE

Profit-oriented grain, livestock and poultry producers no longer limit their thinking about utilizing manure to simply spreading it on the land. Growing concern for rising on-farm energy and protein costs in addition to the realization that many agricultural soils are becoming depleted in organic matter has some producers questioning just how they can utilize manure to best advantage.

As well as having an increased interest in incorporating manure into the soil to conserve more nutrients, some individuals are also considering processing manure to improve its fertilizer value, reduce the volume, decrease the possibilities of polluting water or incurring an odor problem and even to enable energy to be recovered. Making compost from manure, re-feeding as a means of lowering feed costs or producing methane from manure to lower on-farm energy costs are three examples.

Many of the reports or journal articles one reads today present opposing viewpoints about the costs versus benefits of these alternatives for using manure. This section of the report will attempt to give the reader a relatively unbiased review of possible benefits and the current technological feasibility of each alternative, as well as the approximate costs that might be incurred in adopting one of these alternatives under varying situations.

Composting Manure

Composting is a process in which organic solids (such as manure) are digested by bacterial action, leaving the solids in a stable condition which will undergo little or no further decomposition.[1]

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[1] Miner, J. Ronald (ed) 1971. Farm Animal Waste Management. North Central Regional Research Publication 206, Iowa Agr. Exp. Sta. Spec. Rep. 67, quoted in Managing Livestock Wastes, Proc. 3rd. Int. Symposium on Livestock Wastes, 1975. p.485

There are both pros and cons to composting manure. On the positive side, the process generates few offensive odors, and any pathogens or weed seeds in the raw material are destroyed because of the high temperatures reached during the composting period. Composting also reduces the volume of material by about 25 per cent[1], resulting in lower transportation costs when the product is applied to land at some distance from its source.

Because the nitrogenous wastes in raw manure undergo changes during composting, they are more readily usable by growing plants. Whereas only about 50 per cent of the nitrogen in raw manure is available to plants in the first year, and one-half of the remainder becomes available each suceeding year, approximately 90 per cent of the nitrogen is available in composted manure. The reason for this is that microbes found in raw manure compete for nitrogen with growing plants in the soil where manure was applied. In compost this competition is eliminated.

Adding compost to the soil may not be as useful in soil-building as adding raw manure. Compost will not stimulate a rapid growth in the soil organisms that produce binding agents needed for good aggregation. Therefore the soil may be more susceptible to erosion and less able to take in moisture than if raw manure had been added.

Widespread composting of manure on farms has not occurred. In the western United States where there are very large beef feedlots and dairy farms, and the climate is relatively mild year-round, there are several commercial scale composting companies. American farm journals have also reported on a number of smaller-scale livestock and poultry producers who compost manure, either for use on their own farms or for sale to the public.

There are several reasons why Canadian livestock and poultry producers have not taken much interest in composting manure. Canada does not have the large scale feedlots and dairy farms found in the U.S.; the Canadian climate is more severe than in most of the U.S. and therefore makes composting more difficult; and the Canadian market for compost has not been developed to the extent it has in the U.S.

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1 Grub, W. J.D. Martin and L.L. Keaton. 1970. Aerobic Stabilization of Beef Feedlot Waste. Paper presented at the 1970 Winter Meeting, American Society of Agricultural Engineers, Chicago, Illinois.

In addition, there has been very little research or reporting on practical, cost-effective ways of composting animal or poultry manure, compared with such alternatives for handling and utilizing manure as methane generation or recycling manure as a feed. Most people don't even consider composting as an alternative for handling manure on a large scale, but most do recognize the benefits of using compost in their vegetable or flower gardens. The most likely reason for this apparent inconsistency is that researchers and equipment manufacturers haven't demonstrated adequately the benefits of composting or the availability of affordable farm scale equipment for composting. There seems to be a general impression among farmers that a) equipment for composting large volumes of manure must be terribly expensive or b) labour requirements are too high to warrant going to the trouble of composting manure, or c) if their neighbors see them composting manure they will be labelled "organic farmers." This term has developed a poor connotation over the past few decades, during which farmers have gone to extensive use of summerfallowing, stubble burning and inexpensive commercial fertilizers. Now at last, most individuals are realizing that even though it may be more difficult to survive economically in the short run, the long run costs of too much emphasis on the latter methods of farming do not justify the means. Of course, summerfallowing and commercial fertilizers may still be required, but not to the exclusion of practices which can help to maintain the long-term productivity of the soil.

Composting Equipment

Farmers and equipment manufacturers in the U.S. have developed several machines that can be used to shred, aerate and windrow large volumes of manure. For very large volumes of manure, the Roscoe Brown Corporation, Lennox, Iowa, manufactures the Brown Bear integral auger tractor. It is capable of mechanically aerating 3,000 cubic yards per hour.

The Cobey Composter is another high volume self-propelled machine that is diesel-powered and straddles the windrows. It is manufactured by the Eagle Crusher Company, Galion, Ohio. Another large capacity machine (660 tons per hour) is the Scarab. It is a tall chain-driven apparatus, with a belt-driven roller that churns the windrow and re-stacks it neatly. The Scarab was designed by Compost Corporation, Canyon, Texas.

The Mehlaf Machine and Manufacturing Company, Freeman, South Dakota, puts out a turning machine that is tractor-powered with a capacity of about 450 tons per hour.

On a smaller scale, the Easy Over is a tractor-drawn machine that turns one-half of a windrow with each pass, lifting the material up and back onto the windrow. It apparently works best with a hydrostatic drive tractor for slower ground speed. The Easy Over is distributed by the General Compost Corporation, Philadelphia, Pennsylvania.[1]

As might be expected, these machines vary considerably in price, from about $8,000 to $100,000. One would have to decide which machine(s) may be affordable based on the volume of manure to be handled and how operating costs (especially labour) would vary between machines.

For small scale livestock or poultry operations, ingenuity to modify a conventional manure spreader may be all that is needed to compost manure.

One Minnesota farmer[2] uses a front-end loader and modified manure spreader for composting. Manure is removed from turkey barns and piled in six-foot windows. It is then turned a minimum of three times and up to 10 times before composting is complete. The total cost of composting and delivery to other farms within a 25-mile radius is estimated at $20-$25/ton. The cost of trucking and application (using lime spreader trucks) is charged out at $3.50 per acre or actual cost, whichever is less, within a 25-mile radius of the composting site. Beyond the 25-mile radius delivery costs 7¢ per ton per mile. On orders exceeding 100 tons, the compost is priced at 10 per cent below the local cost of commercial fertilizer on an N/P/K basis.

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1 Specialized Equipment For Composting Manure. Compost Science, V.18, No. 6, p. 16-17, Nov/Dec., 1977.

2 Composting Manure: A Burden Turns Into A Opportunity. Hoard's Dairyman, March, 1983, p.76-78.

Three years of field trials on corn, supervised by a private crop consulting firm, showed that this compost produced comparable yields to commercial fertilizers, but at lower cost. With the compost containing approximately 35, 80, 60 pounds of N, P and K per ton respectively, compared with 120, 70 and 180 pounds on N, P and K in the commercial fertilizer, the composted land netted from $15-$40 per acre more.

Researchers at the University of Maryland[1] in the early 1970s attempted to develop a mechanized aerobic composting system sized for typical dairy operations in the northeastern states and operated satisfactorily in that climate. The researchers wanted a uniform, high quality compost with good market potential.

The composting system they designed and tested moved the manure through an 18-meter channel in approximately 15 days. Oxygen was supplied to the mass with a continuously operating centrifugal fan attached to an airduct divided into five sections so that each 3.7 meter-long section of the channel received a supply of oxygen. A transversing elevator located in the channel stirred the composting mass and moved the material along the channel. A pole building with open sides housed the composting channel so that excessive moisture would not be a problem in making the compost.

The research report did not show how annual costs for the composter would compare with the economic value of the compost produced. However, one can assume that each of the 80 cows (1200 pound average weight) would produce 18 tons of manure per year at 20 per cent dry matter. Reports indicate that about two-thirds of the dry matter weight of manure would be available as compost. Therefore the amount of compost produced from an 80-head dairy herd would be:

80 head [(18 tons/head x .20) (.67)] = 193 tons

Assuming that each ton of compost would contain 35 pounds of nitrogen, 80 pounds of phosphorus and 60 pounds of potassium valued at $.28, $.12 and $.12 per pound, respectively, the compost would be worth $5134, or approximately $64 per cow, based on its nutrient content alone.

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[1] Hunsel, J.W. and G.B. Willsonz. High-Rate Mechanized Composting of Dairy Manure. Proceedings of the 3rd International Symposium on Livestock Wastes. American Society of Agricultural Engineers, St. Joseph, Michigan. 1975

Since the nutrient value of the raw manure from 80 dairy cows would be approximately $70 per cow it doesn't seem reasonable to incur the extra composting costs or the time required to produce the compost. However, there may be benefits to composting which, in some situations, will justify the additional costs. For instance, composting does decrease the volume of manure needing to be utilized, it produces a relatively stable, odorless product, and a commercial market can usually be developed for bagged or bulk compost at a price that provides a reasonable return on investment.

Skilled management is required to make good compost. Particular attention must be paid to maintaining a moisture level of more than 40 per cent throughout the composting process and frequent, thorough mixing is needed to complete the process in a short time. Under good conditions composting requires about four weeks.

In addition to utilizing composted manure as a soil conditioner and fertilizer, it also has potential for use as bedding or as a feed supplement.

Production of Methane From Manure

Biogas or methane production through anaerobic digestion of organic matter (such as livestock and poultry manure) may one day be an integral part of a combined manure management and energy production system on farms throughout the world. However, at present, the economic feasibility of producing methane gas from livestock or poultry manure is questionable.

There are already methane digestors on many farms throughout Europe and Asia, and some on-farm systems are now being built or in operation in the United States. Canada has not kept pace primarily because of relatively lower priced conventional energy sources to the present time, and a northern climate that requires a higher percentage of the energy produced just to maintain the temperature of a digestor.

In a simplified explanation, anaerobic digestion of manure is a process whereby bacteria, in the absence of oxygen, break down the organic matter in manure and produce methane gas as a by-product. The

methane gas has potential for on-farm use in heating buildings, grain dryers, etc., as well as running stationary engines and generators in producing electricity to offset rising energy costs.

As a result of energy cost increases and the need for better pollution control on many livestock and poultry farms, significant progress has been made in the last few years in advancing research in North America on methane production. A mere concept just over a decade ago, it has now been technologically proven and may be economically attractive under certain conditions.

The economic feasibility is site specific, depending largely on the size of operation, how efficiently the gas can be produced, how efficiently the gas can be utilized and how much of the energy produced is needed to maintain the temperature of the digestor. Economies of size are apparent when costing out methane production systems and large livestock or poultry operations are the most likely candidates for such a system. Other factors affecting the financial picture are current prices for conventional sources of energy (oil, natural gas, gasoline, propane and electricity), capital and operating costs of the digestor unit and the opportunity cost inherent in putting money into the methane system instead of in other production alternatives for the business.

There are actually several energy sources available from anaerobic digestion. The ability to utilize each source will provide optimum benefits and result in easier justification of a digester system from an economic point of view. The initial energy source is biogas which is approximately 60 per cent methane and 40 per cent carbon dioxide (CO_2). The biogas can be burned directly to heat buildings, etc.; the biogas can also be burned in an engine-generator to produce electricity. Waste heat from the engine can be used to maintain the temperature of the digestor, or possibly as an energy source for ethanol production (providing an economical system can be developed). By separating the digested residue (effluent) into solid and liquid fractions, the solids can be used as a soil additive, livestock feed ingredient or a bedding material for dairy operations. The liquid can be used as a fertilizer for field application or possibly even as a nutrient source in aquaculture - the rearing of fish.

Advantages and Disadvantages

One of the main advantages of producing methane from manure is the pollution control that is achieved through the process. Additionally, nutrients are retained in the by-product and, although the fertilizer value may be slightly reduced, the nitrogen in the effluent is actually more readily available to plants[1].

On the disadvantage side are the size of capital investment needed and the high level of management necessary to do an efficient job of producing methane, as well as the larger volume of effluent to be handled if dilution water is needed to reduce the solids content of the product going into the digestor.

Many digestor systems developed to date have given the operators mechanical problems, especially in pumping wastes in and out of the fermenter tanks. Mixing, screening and plumbing (gas leakage, corrosion, etc.) have also been problems, especially during the start-up phase.

From an extensive literature review several conclusions can be drawn about the state-of-the-art in methane production and its potential for the future:

(a) the primary objectives of installing a waste-to-energy system, such as a digestor, are usually two-fold:
    1) for environmental protection and more efficient waste management, and
    2) to reduce the cash outlay for conventional sources of energy.

[1] Nitrogen in the effluent is in the ammonia form, therefore there is a greater possibility of N losses, and the effluent in storage should be covered. It is also necessary to incorporate it into the ground to avoid excessive nutrient losses when land spreading, a practice that may or may not be feasible for a specific operation.

(b) at current prices for natural gas, electricity, etc., most researchers agree that methane production from manure should be considered primarily as a manure management process and secondarily as an energy cost reducer. The process is an excellent means of controlling pollution and reducing odors while still conserving the nutrient value of the effluent for land fertilization. The usable energy produced is simply a bonus.

(c) the most practical way of using methane on the farm depends on the specific farm situation. If methane gas is being produced year-round, using it to generate electricity may be most practical since electrical demand is less seasonal than the demand for heat. In their report on fuel and fertilizer production from dairy manure, Feddes et al[1] found that when biogas is used for heating rather than electricity generation, a dis-economy of scale may exist because of the production of surplus gas with no economic value in summer.

(d) the three basic by-products that can be recovered from anaerobic digestion of livestock and poultry manure are:

1) biogas (methane)
2) liquid fertilizer, and
3) a biomass solid (cake) for use as a soil amender, bedding material or feed product.

As stated previously, when all three can be used or marketed, the system has the best opportunity of being economically viable.

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[1] Feddes, J.J.R., J.B. McQuitty and J.T. Ryan. Fuel and Fertilizer Production from Dairy Manure. Dept. of Agricultural Engineering, University of Alberta, Research Bulletin 80-1, March 1980.

(e) poultry manure is more difficult to use in a digestor than manure from hogs or cattle because of the sand and feathers which can plug the system unless they are successfully filtered off. If this problem can be overcome, poultry manure actually has a higher energy content and can produce more methane than cattle and hog manure. It is estimated that a cubic foot of hog manure will produce 17,400 BTUs of energy; dairy cattle manure will produce 16,500 BTUs, whereas layer manure will produce 37,200 BTUs[1].

(f) even small amounts of antibiotics or hormones in the manure can kill the bacteria in a digestor and stop the digestion process.

(g) anywhere from 20 to 70 per cent of the gas produced by the system may be needed to heat the digestor. The amount will vary by season and the system design. Super insulation, heat exchangers and below-ground installation (possibly using solar collectors) should be considered in northern climates as a means of maintaining digestor temperature and improving the efficiency of the system.

(h) obtaining financing to build a methane digestor can be a problem because the concept is relatively new. Since most lending institutions are fairly conservative, they will want to see a similar system in operation before committing any money.

(i) a number of U.S. companies offer turnkey systems for converting manure to methane. Many of these systems are designed for large farming/feedlot operations (200 dairy cows, or the equivalent) and prices are upward of $80,000. For smaller operations a few companies and some ingenious individuals have designed relatively simple methane digestor systems at considerably lower costs, using commonly available materials and

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[2] Sweeten, John M. Methane from Manure: Fact or Fantasy? Texas Agricultural Extension Service, May, 1978.

construction techniques. While less costly initially, some of these systems also have a shorter lifespan, may have higher operating costs (labour costs especially) and will likely not have the monitoring and safety control devices found in the higher priced systems.

(j) regulatory aspects require high standards of safety, which increase the costs of the facility.

(k) a high management component is required. Methane production is a somewhat complex biological process requiring a high degree of system supervision and control. Many producers do not have the time to properly manage an anaerobic digestor.

Biogas (Methane) Production Levels

Natural gas, with methane as its major component, contains about 1,000 BTUs per cubic foot. In comparison, biogas containing about 60 per cent methane and 40 per cent carbon dioxide has a rating of approximately 600 BTUs per cubic foot.

As a general rule, about 12 cubic feet of biogas are produced for every pound of volatile (biodegradable) solids utilized in the digestion process. During a practical digestion time of 10 to 18 days, between 35 and 60 per cent of the volatile solids will be destroyed. Based on the figures in Table XIII for the amount of volatile solids excreted each day by different types of livestock and poultry, from 27 to 62 cubic feet of biogas would be produced, yielding from 16,300 to 37,200 BTUs of gross energy on a daily basis. Depending upon system design and the environment in which the digestor is operating, between 20 and 70 per cent of this gross energy will be needed to maintain the temperature of the digestor and to operate pumps and mixing equipment. Assuming an average annual requirement of 30 per cent to maintain digestor temperature, the net energy produced varies between 11,000 and 25,000 BTUs per 1,000 pounds liveweight for dairy cattle, swine, beef cattle and poultry.

TABLE XIII ESTIMATED METHANE PRODUCTION POTENTIAL FROM FRESH LIVESTOCK AND POULTRY MANURE
(per 1,000 lb. animal body weight)

Parameter	Swine	Dairy Cattle	Beef Cattle	Poultry (Layers)
1. Volatile solids excreted, lb./day	4.8	8.6	5.9	9.4
2. Estimated reduction of volatile solids, in per cent	50	35	45	60
3. Gas yield per pound volatile solids destroyed, cu. ft/lb.	12	9	13	11
4. Bio-gas production, cu. ft/day	29	27	35	62
5. Gross energy production, BTU/day	17,400	16,500	20,700	37,200
6. Net available energy, BTU/day	12,000	11,000	14,000	25,000

Source: Sweeten, John M.. Methane From Manure: Fact or Fantasy? Texas Agricultural Extension Service, May, 1978.

Economic Feasibility

The economic value of digestor gas can be determined by examining how much conventional energy it can replace, the present cost of conventional energy and what it is likely to be in the future.

Table XIV gives the cost per million BTUs for various types of conventional energy. As an example, assume that a farm currently uses 1,200,000 cubic feet of natural gas. To replace this amount of natural gas with the gas from a methane digestor would require 2,000,000 cubic feet, having a value of $3300 based on a price of $2.75 per million BTUs for natural gas. If the methane were to replace propane, the value of the methane would be $11,756, based on a price for propane of $.87/gallon[1].

[1] Alberta natural gas prices increased between 5.7 and 15.5 per cent per year between 1978 and 1983 and are expected to continue to increase at an average annual rate of about 10 per cent into the foreseeable future.

TABLE XIV A COMPARISON OF ENERGY PRICES AND COST PER MILLION BTUs

Energy Source	Retail Price (1983)	BTU/Unit	Cost/Million BTUs
Natural Gas	$2.90/GJ[1] ($2.75/MCF)	1000/cu.ft	$2.75
Propane	$ .19/litre ($ .87/gallon)	109,956/gal	$7.91
Fuel Oil (diesel)	$ .28/litre ($1.27/gallon)	156,000/gal	$8.14
Electricity	$ .05/kwh	3414/kwh	$14.65

The cost of a digestion system for a particular farm or feedlot depends on many factors. The degree of automation and safety control features, the size of digestor required (depending on the amount of dilution needed), the additional investment required over and above the current manure handling system, how the biogas is to be used (heating only, electricity, re-feeding of solids, etc.), the type of materials to be used for the digestor, and the method or materials used to insulate against heat loss in the digestor all affect the total costs of the system.

It is necessary to evaluate each situation individually to see whether biogas (methane) production will be economically feasible. Individuals may be able to reduce costs by obtaining some of the components of the system through salvage yards, etc., by using their own labour to build some of the system, or by opting for a more labour-intensive system instead of one that is highly automated.

From a practical point of view and based on past research studies, biogas production for on-farm use should be considered only for farms where livestock or poultry are kept in total confinement year-round and where the biogas can be used at a consistent rate through-out the year. In milder climates, this would include situations where cattle or hogs are kept out-of-doors in fully paved yards, where manure can be scraped and collected frequently for use in a digestor. However, under local conditions this would be impractical.

An economic analysis of producing biogas from dairy cattle manure, was conducted by Feddes, McQuitty and Ryan at the University of Alberta

[1] Gigajoule

in 1980[1]. It showed that, for dairy operations where the gas was used for heating or electrical purposes, and there was no value given to the residue, biogas production was not economically feasible under 1980 energy prices. In fact, the researchers found that the cost of energy from biogas would be from three to 20 times more expensive (depending on the process) than energy purchased commercially.

Biogas production for dairy operations often isn't practical since dairy cattle, on most farms, are run on pasture during the summer and therefore the methane generating equipment would sit idle through part of the year. In addition, the "cake" residue which could be obtained by including a solids/liquid separator in the system cannot be used as readily for a feed ingredient as it might in a beef feedlot operation. Options for using the residue in a dairy operation are to: (a) bag and sell the residue commercially as a soil conditioner, (b) utilize the residue as a substitute for straw or shavings currently used as bedding for the dairy cattle, or (c) a combination of both. However, with a solids/liquid separator costing around $25,000, the amount of residue obtainable from even the larg t dairies in Alberta would not be worth enough to pay for the extra cost of the separator and the cost difference between biogas (methane) and conventional energy sources at current price levels.

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[1] Feddes, J.J.R., J.B. McQuitty and J.T. Ryan, Fuel and Fertilizer Production From Dairy Manure, Dept. of Agricultural Engineering, University of Alberta, Research Bulletin 80-1, March 1980.

Manure Recycling For Use In Livestock Rations

As commercial protein supplements continue to increase in price livestock producers are becoming more interested in the feasibility of recycling manure to cut feeding costs.

Farm animals excrete from 30 to 50 per cent of the dry matter they consume. However, the process of recapturing a part of the excreted nutrients to refeed is a much debated topic and a practice which gets mixed reviews from producers and practising agrologists alike.

Extensive research has continually shown that livestock and poultry manure can be efficiently recycled as a feedstuff for growth or maintenance of animals, but manure refeeding takes more careful management than a conventional grain feeding program before the benefits can be realized.

In 1978, a task-force of eminent authorities on animal nutrition, agricultural engineering, toxicology and entomology, microbiology, law and the environment, published a report for the American Council for Agricultural Science and Technology (CAST) on feeding animal manure[1]. This report confirmed there is substantial nutritional value in animal manure, particularly for cattle and sheep since they are better able to digest fiber and can utilize non-protein nitrogen (NPN). The report also confirmed that nutrients from manure are used just as efficiently as those from other feed sources with equivalent nutrients and that neither the quality of animal products nor their palatability is affected when processed manure is fed at nutritionally acceptable levels.

Where it is practical to utilize whole manure (feces and urine) from livestock or poultry, a valuable protein supplement can be obtained for growth or maintenance of cattle, sheep or hogs.

Poultry manure has been shown to have a higher nutritional value than cattle or hog manure. The two forms of poultry manure that have received most attention are broiler litter and caged layer manure. Broiler litter is a mixture of manure and a litter base material such as straw or wood shavings. Its moisture content is 10 to 20 per cent and some water (or other liquid) must be added to the material before ensiling.

[1] Feeding Animal Wastes, Council for Agricultural Science and Technology, Report #75, Agronomy Building, Iowa State University;, Ames, Iowa 5011 June 22, 1978.

It is easier to handle and utilize as a feed ingredient than caged layer manure which contains no litter base material and has a moisture content as high as 75 per cent. Barley or some other grain is usually mixed with caged layer manure to reduce its moisture content and increase the energy level of the ration.

Research has shown that both types of poultry manure provide nutritionally acceptable high quality protein supplements that can be mixed with conventional feeds (grains and roughages) for use in ruminant growing/finishing rations to achieve competitive, but cheaper gains than the usual forms of protein supplement.[1]

Although cattle manure is lower in nutritional value than poultry manure, it has adequate nutritional value as a ruminant feed. Since cattle manure is relatively low in protein and energy, it is best suited as a feed for animals in low production (such as the beef cow herd) or for use at a low level in rations for high-producing animals. In research where the nutrient content of manure-supplemented rations and control rations were similar, performance was also similar.

There appears to be limited refeeding of hog manure to date. Where solids are being separated from liquid hog manure and refed to gestating sows, materials handling can be a problem. Since most hog operations are set up for dry feed and the separated material is actually only a semi-solid, it is very difficult to handle. An additional drawback is that the material cannot be stored because of putrefaction problems. One of the reasons that livestock producers often invest in a solids separator is to reduce the solids buildup in a pit or lagoon. Without solids separation the storage facility can soon plug up. It must then be dredged at a high cost or else a new storage facility must be constructed. A major benefit of refeeding separated solids from hog manure back to hogs may be the increased level of natural disease immunity that seems to develop in the sow herd.

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[1] Cross, D.L. G.C. Skelley, et al. Efficacy of Broiler Litter Silage for Beef Steers. Journal of Animal Science. Vol. 47, No. 2, 1978.

Where aerated liquid manure is to be used to flush a confinement livestock building, the process is both easier and cheaper if a solids separator forms part of the manure handling system. The resulting solids can be used as a soil conditioner, bedding or feed ingredient. Some type of drying will likely be required with the first two of these options and storage in an oxygen-limiting environment is usually recommended if the solids are to be refed, so that harmful pathogens can be eliminated prior to refeeding.

Since most of the nutrient value in manure remains in the liquid fraction when solids separation occurs, the separated fibrous solids should be thought of primarily as a roughage extender or fibre source for maintenance of livestock rather than for growth.

From a review of the literature it appears that refeeding separated solids can reduce feed costs by as much as 25 per cent, although a 5 or 10 per cent reduction is probably more common. The actual reduction in cost will depend on what type of manure solids are being used; how fresh manure is when it is collected; the quantity of manure that can be collected, processed and stored for refeeding; the percentage that can be used in a refeeding program and the cost of collecting, processing and storing the solids.

SECTION VII

SUMMARY AND CONCLUSIONS

Much work remains to be done in demonstrating how valuable livestock and poultry manure really is in maintaining soil productivity.

Results of long term annual application of manure to crop land in various parts of Europe and North America have shown that crop yields on manured land or land manured and supplemented with fertilizer can equal or exceed yields on adjoining land where only commercial fertilizers have been used.

Although it is difficult to prove conclusively, there is reason to believe that worsening problems of wind and water erosion, as a result of decreasing soil organic matter, could be slowed down or even reversed if manure were used more judiciously.

Following the advent of relatively inexpensive commercial fertilizers, manure was considered as nuisance and often disposed of at least cost. Not only were commercial fertilizers affordable, they were also easier to handle than manure and it was also easier to know how much of each nutrient was actually applied to the soil to meet a crop's specific requirements. Enough fertilizer could be purchased each year to fertilize the whole farm whereas the quantity of manure available may only have been enough to fertilize some of the land, with commercial fertilizer still required for the balance. Advertising also helped convince the farmer that commercial fertilizer would provide everything the soil required.

This publication attempts to show, through examples, how valuable manure can be with proper handling. Section III provides some data which show the approximate nutrient content and the annual value of nutrients found in the manure from various types of livestock and poultry. Additionally, a dollar value is also placed on the organic matter that manure applications can help maintain within a soil. Perhaps further research can assist in placing an economic value on improved soil tilth and water-holding capacity as a result of manure application.

Section IV shows how a partial budget can be used to evaluate the overall effects to a business of changing the way manure is handled on the farm. In this example a dairy farmer wants to do away with the daily drudgery of hauling manure and avoid spreading manure on frozen ground by installing a concrete manure storage slab near his barns. The partial budget analysis shows that added costs would out-weigh added benefits and he would have to justify the investment on some basis other than economics. Other examples (Section V) show the benefits and costs that one might expect as a result of injection or plowdown of manure. The example used to evaluate the costs and benefits of direct injection of manure shows that between 360,000 and 106,000 gallons of manure would have to be hauled annually to offset the additional costs incurred when a $3200 injector unit was mounted on a tractor-drawn 2250 gallon liquid manure tank. Volume depends on whether the benefits accruing as a result of injecting the manure relate to nitrogen savings alone, nitrogen savings plus tillage or nitrogen savings, tillage and odor control. In comparison, plowdown immediately following spreading of manure resulted in higher ownership and operating costs. Therefore, a larger volume of manure would have to be hauled to cover the cost of plowdown.

The last example in this publication (also in Section V) compared the cost of owning and operating manure handling equipment with hiring a custom manure-handling service. For a hog producer who sells 1,000 finish-weight hogs a year and also has 500 feeder-weights on hand, there is little difference in cost between the two manure handling options. Either larger or smaller volumes of manure or different sizes of equipment may change the economics of one option versus the other.

The final section (VI) reviews the state-of-the-art with respect to three fairly controversial alternative uses to conventional land application of manure. Composting of manure, production of methane from manure and recycling of manure for use in livestock rations will all remain manure utilization options in the future. The economics will determine their prominance of position.